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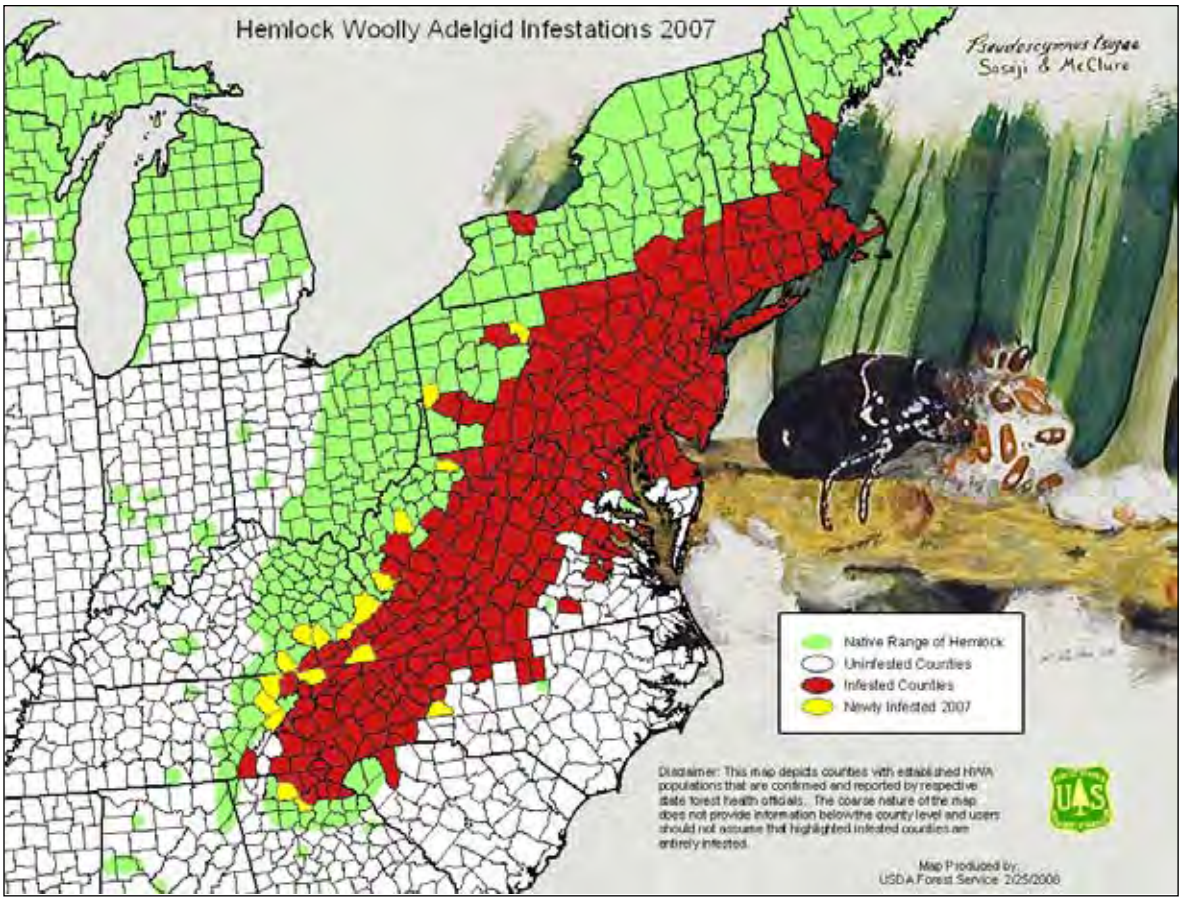
Hemlock Woolly Adelgid

Fourth Symposium on Hemlock Woolly Adelgid in the Eastern United States

Hartford, Connecticut
February 12-14, 2008



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ESTABLISHING *SASAJISCYMNUS TSUGAE* IN THE SOUTH

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ABSTRACT

Since hemlock woolly adelgid was first found in the Great Smoky Mountains National Park in 2002, about 1.5 million *Sasajiscymnus tsugae* (*St*) adults have been released in hemlock-growing areas in the southeastern United States, including Georgia, North Carolina, South Carolina, and Tennessee. Recovery of *St* one or more years after release has been extremely limited in Georgia, South Carolina, and Tennessee. It has been recovered at a few sites in North Carolina. Most of the releases in the South, however, have occurred in the last three years. The subsequent health of hemlock trees in release areas is inconsistent; in some areas, trees are healthy, have good color and are producing new growth, while in other release areas, trees have died. Research using large tree cages is underway to further assess the survival, establishment, and impact of *St* on hemlock woolly adelgid on eastern hemlock. Monitoring of release sites should continue in southern states to better understand the role of *St* in population dynamics of hemlock woolly adelgid. This information, coupled with a more thorough understanding of the life cycle of the hemlock woolly adelgid in southern states, should assist forest land managers in the development and implementation of appropriate management strategies against hemlock woolly adelgid.

KEYWORDS

Sasajiscymnus, recovery, establishment, biological control, release

INTRODUCTION

The hemlock woolly adelgid (HWA), *Adelges tsugae* Annand, was first found in the southeastern United States in 1998, when it was documented in a few counties in North Carolina. It was later found in the Great Smoky Mountains National Park (GRSM) in 2002 and has since spread into Georgia, South Carolina, and Tennessee. Thus, HWA has spread throughout most of the hemlock-growing areas in the South, though it has not yet been found in Alabama.

Sasajiscymnus tsugae (*St*) (Sasaji and McClure), native to China, has been released throughout the eastern United States during the last decade (Cheah 2004). *Sasajiscymnus tsugae* is the most studied of any of the biological control agents considered for release against HWA (Cheah and McClure 1998, 2000, Sasaji and McClure 1997). Several laboratories in the South are rearing *St* for release on public lands in Georgia, North Carolina, South Carolina, and Tennessee. A rearing laboratory maintained by the North Carolina Department of Agriculture rears *St* beetles primarily for release in North Carolina, a laboratory at Clemson University

produces *St* beetles primarily for release in Georgia, North Carolina, and South Carolina, and a laboratory at the University of Tennessee produces *St* beetles primarily for release in Tennessee, mainly in GRSM. Another laboratory at Harris Young College in Georgia also rears *St* for release in Georgia. In addition, some of the earlier released *St* beetles were provided by rearing laboratories at the New Jersey Department of Agriculture and EcoScientific in Pennsylvania.

The objectives of this paper are to: 1) discuss releases and recoveries of *St* in HWA-infested areas in southern states (Georgia, North Carolina, South Carolina, and Tennessee), 2) discuss ongoing research efforts at the University of Tennessee to assess establishment and performance of *St* in the South, and 3) discuss how these results can be applied by forest managers.

RELEASE OVERVIEW

Since 2002, when the first *St* releases were made in GRSM (Lambdin et al. 2006), about 1.5 million *St* beetles have been released in HWA-infested areas in these four southern states (Figure 1). Of these beetles, approximately 350,000 have been released at about 150 release sites in GRSM. About 73% (n=ca. 110) of these releases have occurred in the last three years.

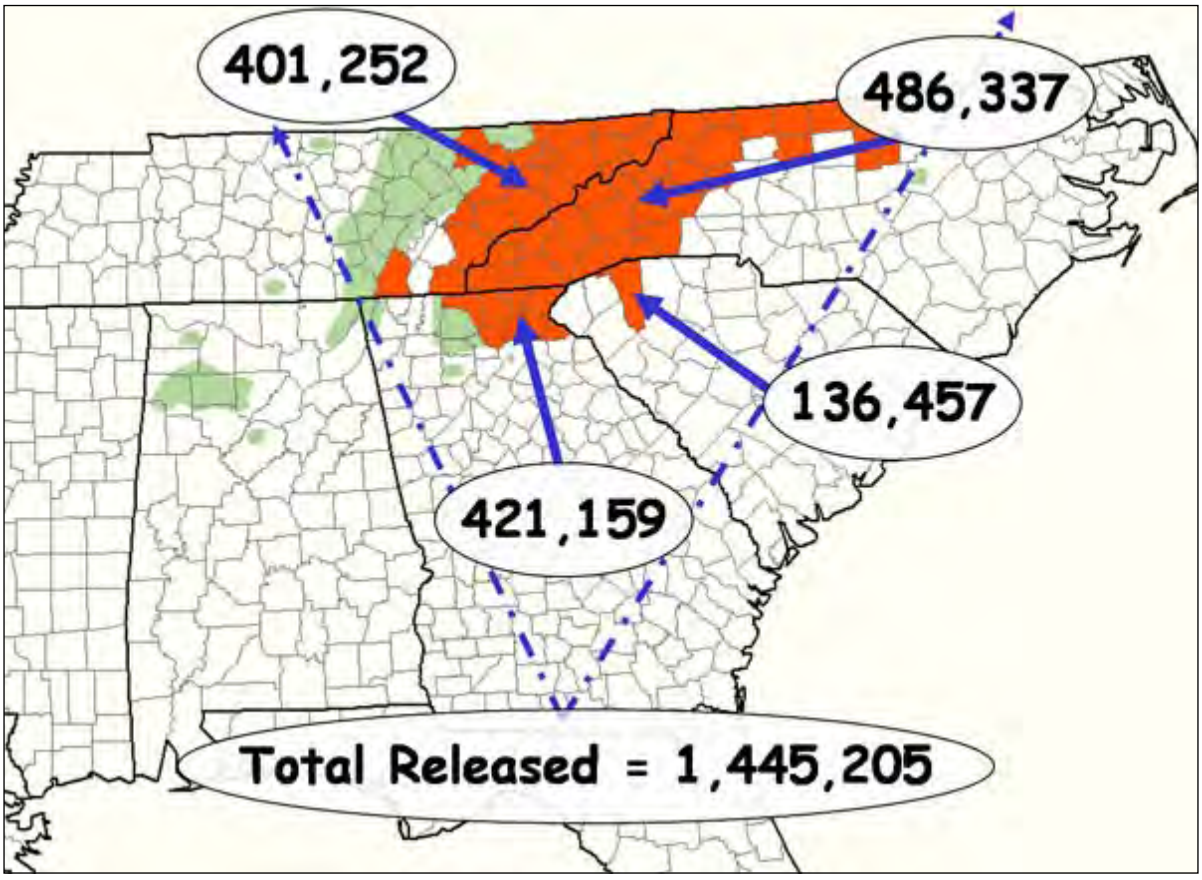

Figure 1. *Sasajiscymnus tsugae* releases in the southeastern United States, 2002-2007. The light colored (green) areas on the map illustrate distribution of eastern hemlock and the dark colored (orange) areas illustrate spread of hemlock woolly adelgid on eastern hemlock. The release numbers are based on data provided by various rearing laboratories and federal agencies; these are conservative numbers and may be slightly less than actual release numbers.

MONITORING AND RECOVERY

Large area-wide, comprehensive efforts to recover *St* in the South have not yet been implemented. In each state, however, researchers and cooperators have placed varying amounts of resources into documenting recovery and establishment of *St* in release areas. Recovery of adults has not been consistent. For example, *St* adults are found often within the first six months following release in all states (as late as early October in Tennessee). Lambdin and coworkers (2006) found three *St* adults four months after release in GRSM in June 2002.

It has been more difficult to document recovery the year following the initial release. In Georgia, no adults have been recovered at six release sites examined thoroughly with a bucket truck for two years (M. Dalusky, pers. comm.). In North Carolina, South Carolina, and Tennessee, only a few adults have been recovered at release sites one or more years after release (L. Burgess and K. Kidd, pers. comm.). Most of these release sites, however, were large areas with small numbers of beetles released. For example, a beetle release in GRSM usually consisted of 1,000 to 5,000 beetles released on several trees in a large area. In western North Carolina, where releases of large numbers of *St* beetles were concentrated on a few trees in a small area, adult *St* have been documented on eastern hemlock for several years (R. McDonald, pers. comm.).

Low recovery of *St* adults also has been observed in release areas in the northeastern United States. The low numbers of *St* beetles recovered at release sites may be attributed to several factors, including:

1. dispersal (following release, the beetles may move from release trees and inhabit other trees),
2. low survival (many of the earlier released *St* beetles were not acclimated to release conditions, which may have attributed to mortality),
3. inadequate timing of releases (adults may not have been released at the optimum time for the appropriate environmental conditions or for the appropriate HWA life stages),
4. mate location (how effectively are males and females locating each other after release and establishment in the field?),
5. predation (what effects do spiders and other established predators have on *St* eggs, larvae, pupae, and adults?),
6. low densities (are the beetles established but occurring at such low densities that their populations cannot be detected through normal sampling?),
7. large sampling area (is the release and sampling areas so large that beetles are easily overlooked?), and
8. insufficient time for populations to increase to easily detectable levels (is two to five years sufficient for populations of *St* to increase to detectable levels?).

Some anecdotal evidence suggests that populations of *St* are established in the southeastern United States. In some areas where *St* adults have been released, trees appear healthy, have good color, and are producing new growth. These release trees appear healthier than those where *St* has not been released. However, in other release areas, trees are in poor

health or have died. Although the healthy appearance of hemlock trees in some release areas is encouraging, the results are inconsistent. In Tennessee and North Carolina, a few *St* have been recovered on HWA-infested plant material collected from the field and brought into the laboratory as food for predators (E. Bernard and K. Kidd, pers. comm.). It is difficult to confirm if this plant material contained field-produced *St* or if the material was contaminated with laboratory-produced *St*.

ONGOING RESEARCH AT THE UNIVERSITY OF TENNESSEE

Several research projects addressing biological control of HWA are underway or have been completed recently at the University of Tennessee. A few of these projects are outlined below.

Life Cycle. The life cycle of HWA in GRSM was documented (Deal 2007) and found similar to that reported in Connecticut (McClure 1989); however, there were a few important differences. HWA sistens began oviposition about one month earlier in Tennessee than in Connecticut, while the progrediens began oviposition about two months earlier in Tennessee. In both regions, sistens began aestivation in July and ended in October. These data suggest that HWA may feed one to three months longer in southern states, which may partially explain the rapid decline in tree health in this region.

Egg Releases. A protocol for the use of egg releases as a complementary means of establishing *St* has been developed and field-tested. The germinal idea of egg releases originated at the New Jersey Department of Agriculture. Temperature appeared to be the most important variable for survival of *St* eggs in the field; mortality of *St* eggs increased greatly as temperatures remained or dropped below freezing (Deal 2007, Grant et al. 2005).

Quantitative and Qualitative Assessment of *St*. A cooperative project with GRSM (Glenn Taylor) will further assess the establishment of *St* and its impact on tree health characteristics. As part of a large-scale study, 22 *St* release areas and 27 non-release/untreated areas have been established in GRSM. At each of these areas, hemlock trees will be intensively sampled for *St*. In addition, evaluation parameters (such as live crown ratio, crown density, crown transparency, twig dieback, HWA infestation level, new growth, etc.) will be assessed. These data will better define the establishment and impact of *St* on HWA in GRSM.

Large Tree Cage Assessments of *St*. The feasibility of using large tree cages (or screened enclosures) to assess establishment of *St* is underway. Cages have been developed and installed in the field. The tree inside each cage will be sampled every three months to assess survival and establishment of *St* as well as its impact on HWA.

DISCUSSION

Do we have unrealistic expectations of recovering *St* beetles at release sites in the southeastern United States, especially so soon following releases? If we consider the total number of beetles released (about 350,000) in GRSM and compare it with the area of land in the Park that has a hemlock component (from old growth to incidental hemlock), about 6.7 *St* adults

have been released per hectare (2.7/acre). From that perspective, it is not surprising that *St* has not been recovered more often.

It is estimated that introduced biological control organisms generally require three to six years, depending upon prey and predator, to become established and begin exerting a noticeable effect on the targeted prey. Van Driesche and Bellows (2006) compared many biological control programs and concluded that, in most of these programs, declines in pest densities caused by introduced biological control organisms occurred over 6-10 generations of the prey. Applying this information to HWA, we should expect to find *St* in three to five years following release and also see declines of HWA. However, because of the high reproductive rate of the parthenogenic HWA females, *St* may require longer to exert pressure on HWA populations.

The vast majority of *St* releases in the South has occurred within the last one to three years. In fact, about 120 of the 150 release sites in GRSM were established since 2005, and two years is not sufficient time for establishment, population increase, and recovery. What is a sufficient time? Three years after release? Four years? Six years? Regardless of how long it takes to recover *St*, mortality of hemlock trees in the South is occurring at an alarming rate (about three years post-detection in most areas). The large tree cage assessments should enhance our understanding of the survival, establishment, and impact of *St* on HWA.

Release of *St* beetles has never been a primary short-term control strategy, but rather a long-term, sustainable and environmentally compatible population reduction strategy to lower HWA populations to non-threatening levels. Efforts to protect hemlocks using insecticides must continue while providing adequate time for establishment and population increases of *St*. This research has provided a better understanding of the life cycle of the HWA in the South and should enable us to better time pesticide applications as well as enhance our niche exploitation of HWA using introduced biological control agents. Egg releases also offer land managers an option to complement field releases of *St* adults when extra eggs are available from rearing laboratories. These egg releases can expand the areas where *St* are released and enhance management of HWA.

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